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On Stable Exponential Cosmological Solutions in the EGB Model with a Cosmological Constant in Dimensions $D = 5, 6, 7, 8$

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Abstract—A D-dimensional Einstein–Gauss–Bonnet (EGB) flat cosmological model with a cosmological constant Λ is considered. We focus on solutions with an exponential time dependence of the scale factor. Using the previously developed general stability analysis of such solutions by V.D. Ivashchuk (2016), we apply the criterion from that paper to all known exponential solutions up to the dimension $7+1$. We show that this criterion, which guarantees the stability of solutions under consideration, is fulfilled for all combinations of the coupling constant of the theory except for some discrete set.

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1. INTRODUCTION

Lovelock gravity [1] can be considered as the most conservative modification of general relativity (GR) in the sense that the equations of motion of this theory are second-order differential equations (as in GR), in contrast to other metric theories, usually leading to fourth-order equations (though there are some other approaches with the same property, for example, the Palatini version of $f(R)$ theory or $f(T)$ theory). Usually, an increase in the order of equations leads to a variety of new solutions, some of them without a GR limit (for example, famous "false radiation" vacuum isotropic solution in $f(R)$), Lovelock gravity being a second-order theory is free from this feature. However, due to rather complicated equations of motion, the Lovelock theory can also contain some solutions without a GR analog. One of such examples are exponential solutions in anisotropic cosmology.

In GR there is a unique vacuum solution for a flat anisotropic Universe, the Kasner solution (which, strictly speaking, is a one-dimensional set of solutions). The scale factors of this solution have a power-law behavior in time. A version of a power-law solution is known in general Lovelock gravity. However, when higher Lovelock terms (starting from the Gauss–Bonnet term) are taken into account, there emerges a new type of solutions with exponential time behavior of the scale factors (i.e., with constant Hubble parameters). Such solutions also exist for a non-vacuum Universe and belong to two different cases. If the matter content is different from the cosmological constant, the solution exists only in a very special case of the Universe with a constant volume. For matter in the form of a cosmological constant, there is no restriction on the volume. In this latter case, all exponential solutions appear to be a subject of rather a strict condition: space is divided into a restricted number (for Gauss–Bonnet theory, maximum three) of isotropic subspaces. The fact that this division is not introduced "by hand" and appears naturally from the equations of motion makes the exponential solutions interesting for model building in multidimensional cosmology. Any application should be preceded by stability studies. The stability of exponential solutions has been recently considered in several papers, in particular, it was shown that in the Einstein–Gauss–Bonnet (EGB) theory, a necessary condition for stability is volume increasing. As for a sufficient condition, a special algebraic relation should be satisfied.

In this paper we consider a D-dimensional gravitational model with a Gauss–Bonnet term and a cosmological constant Λ. Our goal is to check explicitly this relation for all known exponential solutions up to seven spatial dimensions. We note that so-called Gauss–Bonnet term has appeared in string theory as a correction to the (Fradkin–Tseytlin) effective action [2–6].

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